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INTRODUCTION TO TECHNOCRACY

By HOWARD SCOTT

and others

THE JOHN DAY COMPANY, INC.
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WITH AN INTRODUCTORY STATEMENT
BY THE
CONTINENTAL COMMITTEE
ON TECHNOCRACY

AND A SELECTED READING LIST FOR LAYMEN FROM THE LITERATURE OF SCIENCE

TECHNOCRACY, INC.
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None of the contents of this book have been hitherto published elsewhere except pages 39 to 49 which appeared in *The Living Age* as part of an article written by Mr. Scott.

Material for this book assembled and edited by Frederick L. Ackerman, Harold Ward, M. King Hubbert and Dal Hitchcock.

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FOREWORD

Growing public recognition of the importance of the scientific method in the operation of a well ordered society has caused the Continental Committee on Technocracy to be formed. It submits this first authorized volume regarding the work of the research group of Technocracy, in order to provide the interested public of North America with reliable information on a subject so widely —and in great part so inaccurately—discussed.

Although moderate in size, and by no means comprehensive in scope, this book is to be understood as representing the official position of Technocracy, both in regard to its research activities and their social implications. Part I incorporates much of the material which appeared in the preliminary and unpublished report of Technocracy, and adds thereto much that is both new and vital. Every effort has been made to ensure accuracy of statement, and the conclusions presented are to be read in the same objective spirit by which they were elaborated from the factual material at hand and in the growing records of Technocracy.

Part II is written by Mr. Howard Scott, and the reader is urged to regard this statement as basic to an understanding of the approach of Technocracy toward the problem of operating a continental area with modern technological equipment.

In view of the scarcity of material dealing specifically with Technocracy, and by way of indicating the sources

from which it has freely derived its principles and methods, a short bibliography of scientific books is included. It must be clearly understood that this list has been prepared with the needs of the average reader in mind, and is therefore neither comprehensive nor final. Those with scientific background or technical training will easily be able to supplement and enlarge on the suggestions here made—as Technocracy itself hopes to do in the future. Meanwhile the bibliography will have served its purpose if it enforces upon all the necessity of acquiring a sound knowledge of those fundamental scientific concepts which are replacing much of the outmoded—but still orthodox—methods of economic and sociological thought.

The very brief section on "Basic Definitions" is included to assist readers in familiarizing themselves with the fundamental concepts herein mentioned.

The royalty proceeds of this book are to be devoted to the administrative expenses of Technocracy's Energy Survey of North America, which is now being conducted at Columbia University.

The Continental Committee on Technocracy submits this volume to the North American public, with the understanding that it is to be regarded as only introductory to the technical reports which Technocracy as a research body will issue as the progress of its work warrants.

CONTINENTAL COMMITTEE ON TECHNOCRACY.

SOME BASIC DEFINITIONS

> "I often say that if you can measure that of which you can speak, you know something of your subject; but if you cannot measure it, your knowledge is meagre and unsatisfactory."
>
> Lord Kelvin.

"In physical science . . . the first step is to define clearly the material system which we make the subject of our statements. This system may be of any degree of complexity. It may be a simple material particle, a body of finite size, or any number of such bodies, and it may even be extended so as to include the whole material universe."

James Clerk Maxwell, "Matter and Motion."

*   *   *

Mass: The quantity of matter in a body, or, more correctly, the degree of resistance to changes of state exhibited by a body. (*Weight,* however, is an expression of the force with which the earth attracts the body.)

Motion: Change of position (displacement of a body with reference to another body). The determination of displacement involves two quantities: the *length* of the path traversed between the given points, and the *direction* of the path from origin to terminus (Vector).

Force: That which changes, or tends to change, the state of rest or uniform motion of a body. It is only through such changes that force can be detected or measured.

Energy: The capacity of a body or material system for doing work. *Kinetic* energy: Possessed by a body in virtue of its motion; summarized in the formula K.E. $= \frac{1}{2}mv^2$, where *m* is the mass of

the body and *v* its velocity. *Potential* energy: Possessed by a body in virtue of its position or configuration. (The case of water at the top of a fall, of a body suspended above the ground, of a taut cord or a coiled spring.)

Work: A force is said to do work when its point of application is displaced in the direction of its application (Cox). Expressed more generally by James Clerk Maxwell, work is "the transference of energy from one body or material system to another. The system which gives out energy is said to do work on the system which receives it, and the amount of energy given out by the first system is always exactly equal to that received by the second." Bear in mind that in practice allowance must be made for "losses" through friction, air resistance and heat; these losses, however, added to the total of energy effectively transformed into work, always equal the total energy originally expended.

Power: The quantity of work done by a body or material system in a unit of time. More tersely, a time-rate of doing work. This scientific definition of power must be kept clearly in mind in all discussions bearing upon the operation of physical equipment of any kind: no reference to "power" is correct that does not state a quantitative relationship between the factor of Work and the physical dimension of Time.

NEWTON'S THREE LAWS OF MOTION

1. Every body continues in its state of rest or of uniform motion in a straight line except in so far as it is compelled to change that state by impressed force. (This is Galileo's Principle of Inertia.)

2. Change of motion is proportional to the impressed force and takes place in the direction of that force. (From this law is derived the method of measuring force, which can be observed only in relation to changes of state in a body.)

3. To every action there is equal and opposite reaction. (This states that all force is of the nature of a *stress*, that is, a mutual action between two bodies. Force could not exist, nor would it be necessary, if there were no inertia or resistance to overcome.)

THE TWO LAWS OF THERMODYNAMICS

1. The total energy of a body or system of bodies is a quantity which can neither be increased nor diminished by any mutual action of the bodies, though it may be transformed into any one of the forms of which energy is susceptible. (Clerk Maxwell.) This is the great Principle of the Conservation of Energy. Attempts to circumvent or violate it come under the head of *perpetual motion of the first class.*

2. The total energy of a material system (which includes its heat) tends to become uniformly distributed throughout the particles of the system. This process is described as "unidirectional and irreversible," and from any determinate energy state of the system (provided that no indeterminate external force is introduced) it is possible to calculate "the next most probable state" of the system. The final state of complete distribution or equipartition of energy is called the *maximum entropy of the system.* It is this law which in current physical theory is treated as a special case of the theory of probabilities: the state of a material system at any moment is a statistical expression of the combined (and individually indeterminate) states of the particles of which it is composed.

PART I

The Technologist Looks at the Depression

THE state of bewilderment and sense of futility that hang like a pall over the peoples of Christendom are commonly laid to the Great War and the strange peace, conceived in terms of mutual defeat that marked its provisional close. These events are viewed as the immediate causal circumstances that gave rise alike to the decade of golden opportunities and its collapse in the relentless retreat of "values" that continue to march past day after day in columns of three—"high," "low," "close."

But, as everyone knows, there were more remote events out of which the Great War and the unstable peace unfolded. And, so historians, statesmen, philosophers, economists, bankers, business men and politicians explore the background in search of the "fundamental" causes which they discuss in conflicting accounts of their explorations. Thus we are buffeted by events and currents of opinion which bewilder and confuse.

Living in the twentieth century, these explorers of the past would go to their work under guidance of the twentieth century point of view. But it happens in this fourth decade of the twentieth century that the current point of view covers an extremely wide area of thought with rapidly shifting frontiers. Within its boundaries

the ancient principles (habits of thought) which guided men's action in the days of pagan antiquity still do service. We rationalize and debate after the manner of the schoolmen of the middle ages: we think and act under the principles of right, equity, propriety, duty, belief and taste as stabilized in the days of the handicraft guilds of Central Europe.

But during the last century and a half a series of ever changing material factors unfolded at an accelerating rate within the field of industrial activity. Coincident with the introduction of these swiftly moving technological changes there developed, both independently and consequent upon their introduction, a new matter-of-fact way of looking at facts and events and of dealing with an ever-increasing range of problems,—the modern scientific point of view.

The eighteenth century saw the introduction of the powered machine, which was first conceived as an extension of the hand operations of craftsmen. The close of the nineteenth century witnessed the machine process occupying a dominant place in the technological scheme and reshaping men's habits and methods of thinking. The turn of the century marked the introduction and the accelerating rise, under guidance of science, of the modern, continuous technological processes of production. In this new industrial order the machine was no longer conceived as an extension of the hand tool; it became a moving mechanical element in a sequence of events the course and rate of which had been arranged and ordered in strict accordance with the exact quantitative calculations of science. Men in the fields of scientific inquiry and technological research, the same as those directly engaged in technological employment, gradually ceased to think in terms of workmanlike efficiency of a given cause working to like effect; they began to think in terms of *process.*

The work of accounting for the present state of af-

fairs falls, naturally, to those whose interest and preoccupations revolve about the institution of absentee ownership with our system of pecuniary evaluation and pecuniary canons of taste. They explain the present in terms of this institution, its system of evaluation and the range of faiths and beliefs that stand to support it. It follows that these men who so attempt to account for the present situation as well as those who are called upon to do something about it are drawn from occupations most widely removed from the technological and scientific thought and activities which serve to mark off and distinguish the last half century from the entire period of time that lies in the background.

But the men of science and of technology are likewise concerned with the present precarious state of the common welfare and the general atmosphere of futility, and it is not to be wondered at that they should turn their attention to the causal circumstances out of which the present condition of affairs unfolded. Nor is it to be wondered at that they should interest themselves in what should be done about it.

They read the accounts of historians, statesmen and economists with their constant references to a "normal" course of things. To the scientist, this insistence upon a "normal" course of things or a beneficent run of events bars out any serious consideration of the explanations offered. Nor do these scientists and technologists understand why all these explorers should forever busy themselves with the facts of ownership and pecuniary values while ignoring altogether the accelerating rate of change that is going on in the processes of technology. They do not understand the current accounts of what has happened or the proposals as to what should be done about it. For the entire range of facts and events dealt with lies completely outside the range of facts and events with

which they are concerned in their own accounts, viz. the accelerating rate of change in the state of the industrial arts and the corresponding accelerating rate of energy conversion. To these men of matter-of-fact and of quantitative measurements, with their knowledge of our energy resources and our ways and means of turning them to the account of the common welfare, the current proposals looking toward a return to better times are utterly beside the point.

A cleavage has arisen within the field by which things and events are apprehended. The words, phrases and the concepts of modern science and of technology which pass current among men engaged in scientific research and in technological production have no meaning whatsoever to those engaged in business and the affairs of the market, or who direct the financial affairs of corporations, states or nations. And by the same token, to the men accustomed to the exact quantitative measurements of materials and work—that is to say, to the quantitative measurements of energy resources and energy conversion, to the men who deal with the problems of balanced load, the current discussions of "value," of fluctuating prices, of the gold standard, of changing interest rates, of items of pecuniary wealth which are at the same time items of debt,—are merely discussions looking toward a readjustment of the factors which prevent them from doing their work. For the modern technologist does not view production as a process that terminates at a point which may be designated as F. O. B. plant. Production would be a meaningless activity if the goods produced could not be utilized. Hence they view the matter of production and distribution as a single problem—the technological problem of (quantitatively) balanced load.

Through endless books, magazines, newspapers and reports of conferences and discussion, we are familiar with

what the statesmen, bankers, economists, business men and philosophers have to say as to what brought on this depressing state of affairs and as to what should be done about it. While men in the field of science have occasionally explored the general field of the past and have voiced opinions as to the present, the men in technology have had little to say. Since the technologist occupies the center of the stage in the field of modern industry, we may well ask him to indicate what he finds when he explores the background and what he finds when he looks in his matter-of-fact way at current events.

When the technologist explores the past, his interest centers, naturally, upon items of evidence which disclose the methods—the techniques—through which man has turned the things of his environment to account. The records of archaeology yield relatively little that he can use, for men in this field have been preoccupied with other matters than the state of the industrial arts, quantitative measurements of the energy resources available in a given case, and the quantitative relation between the rates at which man has been able to convert energy to use forms. But even so, from the fragments of archaeological explorations and the more recent explorations of scientists, he has been able to put together the outlines of a quantitative record of the changing states of the industrial arts and men's unfolding ability to turn the energy resources of his environment to account. And the outstanding feature of that record is the controlling nature of the prevailing technology at any given time upon the course of subsequent events—that is to say, upon social change. From the viewpoint of the technologist, man has experienced but few sweeping social changes, that is, few conversion changes in the rates of energy; and these are widely separated in point of time. The domestication of the crop plants and the development of them in a dim, historic past thrust

man into a larger control of his environment—that is, to use a technological term, into a new *energy state*. In the same way, the domestication of animals gave him new powers to command and carried him a little further along the way of control. The introduction of these factors, each in its turn, wrought revolutionary changes in the social scheme under which he had lived.

But following these two technological changes man did little from the dawn of history to the middle of the eighteenth century to increase his powers or to alter his energy state. What man could produce during that long period was largely a matter of what he could produce with his hands. Vast stores of energy were available then, as now, but his use of them—his ability to convert energy to use forms—was largely limited to the rate at which he could turn the energy of the food which he consumed into work performed by hand. Man's own body, whether free or slave, was the only energy conversion engine available over a period of countless centuries.

Up to the middle of the eighteenth century the number of man hours required to cultivate an acre, or to quarry a yard of stone, or to transport it or to perform any given piece of work, remained approximately the same as was the case of 6,000 years earlier. We are in the habit of thinking of this stretch of some sixty centuries as one of ever-changing social schemes. It is true, forms of government passed, one after the other; and cultural patterns ran their course from Ancient Egypt, Greece and Rome, to the Middle Ages and the Renaissance of Europe. But to the technologist these sixty centuries cover a steady state of man's ability to deal with the material factors of his environment. It covers a steady state in the rate of energy conversion.

For, during the entire period, the standard of living—the common welfare—was definitely, quantitatively lim-

ited to the work that man could do with his hands, tools and a few crude machines that added little to his power.

That these sixty centuries of recorded history constitute a steady state in respect to the industrial arts, technology and the rate of energy conversion and the social and political schemes that unfolded during the period, will be more readily apprehended when we deal, quantitatively, with the magnitudes of energy resources available during the entire period, and the rapidly accelerating rate of change that has taken place during the last century and a half.

Before we may proceed with the technologist to an examination of the present social structure it will be necessary to establish an understanding as to the meaning of certain terms that he constantly uses and as to what it is that he rates as important.

When he looks at the world he notes that everything that moves, including the human body, does so by an expenditure of energy which may be expressed in terms of calories or joules. An automobile does work because it is able to utilize the heat energy contained in gasoline. A waterwheel turns by utilizing the energy contained in the water in motion at a waterfall. The human body runs by means of the energy contained in the food it "burns." All of these are measurable in calories or joules. And he rates this as a fact of great importance.

All forms of heat-transfer or of work done are said to involve a transfer of energy—energy being the capacity for doing work. Thus a waterfall is continuously expending energy regardless of whether this energy is utilized or not. If a pound of coal is burned the energy in that coal may or may not be used to drive an engine or to do other work. But whether or not work is done, after the coal is burned the energy it contained has been irretrievably spent. It is through the expenditure of energy that we convert all raw

materials into use forms and operate all the equipment which we use. It is through the expenditure of energy that we live.

Now, we can measure the heat energy contained in a pound of coal by burning the coal in a tightly closed vessel surrounded by water and noting the rise in temperature of the water.

One kilogram calorie of heat is the amount of heat required to raise the temperature of one kilogram (1 kilogram = 2.2 lbs.) of water one degree centigrade.

Likewise, the unit of work is the erg or the joule. One joule is the amount of work required to lift a one pound weight to the height of 0.7373 feet. One joule is equal to ten million ergs.

Also, there is a definite relation between work and heat or between joules and calories. If we let a one pound weight fall through a height of 0.7373 feet in such a manner that all of its energy is converted into heat, instead of turning a pulley or lifting a weight, one joule of work is also done. This, in turn, will produce enough heat to raise 0.239 grams of water 1 degree centigrade or heat equivalent to 0.239 gram-calories (1 gram-calorie = 1/1000 kilogram-calorie).

It is in these terms that the technologist thinks when he considers the "standard of living," rather than in dollars, pounds and shillings, francs, marks or rubles.

In all social systems there are various forms and amounts of motion. We shall define as a *social steady state* any society in which the quantity per capita of physical motion, or energy expended, of the whole society shows no appreciable change as a function of time. Such a society would be one in which the methods for the production of commodities and operation of services do not essentially change, or, stated positively, social change involves a change in the technique whereby people live.

On the other hand a society wherein the methods of obtaining a livelihood, or the average quantity of energy expended per capita, undergo appreciable change as a function of time, is said to exhibit *social change.*

Since social change has been defined above in terms of physical action, then any method of its measurement must likewise be physical and all social activity whether in a steady or changing state must obey the laws of physics and must likewise be subject to the limitations imposed by those laws.

The fundamental physical concept for relating and measuring all forms of physical activity is that of work, or energy expended. By work the physicist means the application of energy to mass to produce a resultant change of state.

Upon this basis we can measure quantitatively the physical status of any given social system. Take any *non-machine* society: The total energy used by that society is the energy of the food eaten by man and his domestic animals and the fuel burned. Man himself is the chief engine. The energy per capita is this total amount expended divided by the population.

Prior to the advent of modern science and technology, a little more than a century ago, it is doubtful whether any society had ever exceeded an extraneous energy consumption of 2000 kilogram calories per capita per day. Since all human activity is determined quantitatively by the amount of energy consumed, we can truly say that all history, until recently, has not witnessed an appreciable social change, in the sense herein defined.

The steady state of any social system of the past was set up and limited as such because no nation in history possessed any other engine of energy conversion than that of the human being, limited in size from 125 to 200 pounds and in total output to 1,500,000 foot pounds per

eight hour day. The rate of doing work of the human engine laid down the limits of mechanical operation of any social unit possessing this type of engine alone. No change in the rate of work done in any social system was evident until after the advent of technology in the early nineteenth century. The introduction of other engines of energy conversion in the nineteenth century and the discovery of new materials and new energy sources in the last hundred years have brought about a change of rate impossible of envisagement in any social system founded on the human engine. Not until other energy resources became available through other engines of energy conversion was man in his engine category relieved from the age-long limitations of one of the lowest rates of output per weight for size we know of. The human engine in an eight hour day is only capable of producing work approximately at the rate of 1/10 horse-power during that time.

The first engine of energy conversion, other than the human body, free or slave, that was of social significance, was the crude Newcomen atmospheric steam engine of 1712, of approximately seven horse-power. This engine reached its maximum in 1772 in the Chasewater development with an energy conversion of 76½ H-P. Here is a 765 fold increase of rate over the human engine. In the late eighteenth century, Watt brought out the first true steam engine. This type reached its maximum in the 2500 H-P Corless at the Centennial Exhibition of 1876. The reciprocating engine of conversion reached its maximum rate of output in the marine triple expansion development of the '90's. In this type the rate of energy conversion jumped to 234,000 times the rate of the human engine, as calculated on a twenty-four hour basis, for this engine can work three shifts every day.

The introduction of the turbine and the waterwheel

brought in still newer types of energy conversion. While the first turbines ever made were less than 700 HP per unit, and the first turbine ever installed in a central station was only 5,000 HP, they have risen in rated output until units of approximately 300,000 HP are operated today, 3,000,000 times the output of a human being on an eight hour basis. But the turbine runs twenty-four hours a day. Therefore the total output of the above turbine is 9,000,000 times the rate of output of the first engine of energy conversion socially used.

The first station turbine consumed 6.88 pounds of coal per k. w. hour in 1903. By 1913 the central station coal consumption in the U. S. had fallen to 2.87 pounds per k. w. hour: in 1929 the average was approximately 1.2; today the more efficient stations are operating at less than 1 pound per k. w. hour.

From 6.88 to less than one pound measures this rate of change in three decades.

While waterwheels were known to the ancients as more or less practical toys, even in the eighteenth century, the most efficient size of waterwheels seemed to be limited to twenty feet in diameter, although larger ones were built. The famous pumping machine at Marly which worked the fountains at Versailles was driven by fourteen waterwheels which delivered 75 HP in actual work, or not more than 5 HP per wheel. The waterwheels of the Middle Ages and the ancients can be dismissed as primitive toys, as their installation costs in most cases were not justified by the small increase in the energy conversion rate which they made possible. Their installation was not practical until the development by Fourneyron in 1832 of his original 50 HP turbine type wheel. In 1855 an 800 HP turbine was installed in the Parisian water works at Pont Neuf. Thompson and Francis developed the crude reaction water turbine, but the perfection of this type of

engine did not come until after the development of the steel industry and the discovery of electrical generation.

The water turbines installed in Power House #1 at Niagara Falls have risen in size from 5,000 HP each in 1891 until today we build them over 60,000 HP and could build 100,000 HP units, were it necessary.

Just as we can say that the maximum rate of output of ancient Egypt rarely exceeded 150,000 HP for eight hours on a basis of 1,500,000 adult workers, we can point out that prior to the first quarter of the nineteenth century of our own era, engines of conversion were under two hundred pounds in average weight with an output of 1/10 HP per unit, per eight hour day.

When, only a century ago, the first significant change in the rate of energy conversion occurred, it marked the beginning of a social change, the magnitude and rate of which had never been dreamed of by a pre-nineteenth century brain. But once under way, wave after wave of technological development has swept the processes of each decade into yesterday's seven thousand static years. The first engine, developed by Newcomen, did not survive the century. The second change in energy conversion only survived a century to be replaced by a newer engine of higher output. For six thousand years of social history no change in the rate of doing work was effected except that in the metabolism of the human engine of conversion due to dietary changes. Within the last hundred years we have multiplied the original output rate of that human engine by 9,000,000, in a modern energy conversion unit. Most of this 9,000,000 (or 8,766,000) has occurred in the last twenty-five years.

This tremendous acceleration in the rate of doing work has altered the entire physical complex of social existence. We are able to produce physical substances and forms impossible of production except where a tremen-

dous energy input per day is available. We gather the materials and produce physical forms that could not have been attempted nor probably even envisaged in a social mechanism possessing only that low rate engine of conversion, the human being. This tremendous acceleration in the rate of doing work has reached a point at which the energy available is in such huge volume that we can affect transformations at continually accelerating rates proportional to the amount of energy consumed per given unit of time.

The social mechanisms of the past six thousand years had no means of energy conversion available other than the human body. When tillage was a matter of spading the soil, a man could spade about one-eighth of an acre per day of twelve hours, or at the rate of ninety-six man hours per acre. Today the large tractor, drawn sixty disc or duck foot of modern power farming, has reduced the man hours per acre to 0.088. Thus we have reached a rate of tilling soil which is more than eleven hundred times that of the human engine.

Brickmakers for over five thousand years never attained on the average more than 450 bricks a day per man, a day being over ten hours. A modern straightline continuous brick plant will produce 300,000 bricks a day with twenty men on the machine. Even a century ago in these United States one man produced not more than twenty-five tons of pig iron per year, while it took another man a year to produce eight hundred tons of iron ore. In 1929 in one pit we mined ore on the Mesabi Range at the rate of 20,000 tons per man per year and in six weeks moved a greater tonnage than that of the Khufu pyramid at Gizeh, while our best blast furnace technique has made it possible for thirty men working in crews of ten to produce 300,000 tons per annum or for one man to produce at the rate of 10,000 tons of pig iron per annum.

In 1830 the United States had slightly over 12,000,000 population and was witnessing but the crude beginnings of new means of energy conversion, for at that time from coal and timber it was producing less than seventy-five trillion B.T.U. (British Thermal Units) per annum in order to drive its factories, its ships and operate all other equipment. Nineteen twenty-nine saw the United States with a population of approximately 122,000,000—an increase of ten times, but its energy produced had risen to almost twenty-seven thousand trillion B.T.U. or three hundred and fifty-three times the energy conversion from coal and water power of 1830. Most of this increase has occurred since 1900, for in that year we only produced eight thousand trillion B.T.U.

While our bituminous coal production has leveled off to slightly over 500,000,000 tons per annum, we are consuming ever-increasing amounts until now of gas, oil, and hydro-electric power, tending, temporarily at least, to limit the total rate of coal consumption.

We are face to face with an immediate depletion of certain energy and mineral resources in combination with this rising productive capacity. We may very well ask ourselves where we shall obtain the iron ore of the future even if there were no other wastes involved, when we consider the annual depletion due to the production of 22,000,000,000 tin cans, most of which go to decorate our garbage dumps.

Assuming that we have the same number of oil consuming units (motor cars) as we have today, we may also ask where the oil is going to come from in 1940. Oil production rose from its discovery in 1859 to 64,534,000 barrels in 1900. In 1929 it had jumped to a billion barrels a year. Let us realize that the average oil pool drops 96% from flush flow within four years. Of the approximate 1,000,000 oil wells drilled on the North American conti-

nent since 1859, oil is still coming from 323,000 wells, but less than 6,000, or about 2%, of the latter supply the bulk of our oil.

If one plots a graph of the production capacity expansion of any basic industry on this continent, such as iron or steel, for the last 100 years, he will note that the industry showed no great development until about 1870. After 1870 and until the turn of the century the development of every basic industry increased at a rate which accelerated with time (in other words the annual rate of increase of production was itself increasing with time).

Finally, in the development of each industry a point was reached after which the rate of expansion became less each succeeding year—the rate of production capacity expansion changed from a period characterized by an ever-increasing acceleration to one of an ever-decreasing acceleration.

The point on the curve at which this occurs is called the "point of inflection." The point of inflection for American railroad development occurred in 1900. The inflection point on a composite curve, made up of the basic industries in the United States, occurred about the year 1921.

Similarly, if one plots the total number of plants or amount of physical equipment for any basic industry during the last hundred years he will note that the total number of plants increases with time until their total reaches a maximum. Then with technological improvement and resulting quantity production methods, obsolescent equipment is abandoned and the total number of operating plants declines.

This is clearly illustrated, for instance, by the clay products industry. In 1849 there were 2121 plants in the United States. The number increased to a maximum of 6535 plants in 1889 and then by 1929 had declined to

1749, or below the level of 1849, and all this with an increasing rate of production and increase in total production capacity.

During the period of industrial development which we are considering, the number of man hours of human effort required per unit output was greatest one hundred years ago and has declined steadily ever since, approaching the limit of zero in all our best practices. The total employment in a given industry began small and increased as the industry expanded until as a result of technological improvement and larger scale mechanization the rate of replacement of men by machines exceeded the rate of expansion of the industry, at which time a maximum of employment was reached and since that time total employment has declined. It has been observed in the major industries that, wherever mechanization has taken place, employment or man hours tends to become an inverse function of the rate of total output and, after passing the peak, tends to decline proportionally to the decline of the energy per unit produced.

In 1920 the railroads of the country employed 2,160,000 men; in 1930 they employed 1,518,000 men, and in December 1931, 1,164,000 men. In 1929 the carriage of freight was 6.3 per cent greater than in 1920.

The automobile industry reached its maximum employment, exclusive of body and accessory plants, in 1923, producing 4,180,450 units with 241,356 employees. In 1929, with 226,116 employees and with a total output of 5,621,715 cars, man hours per car fell from 1,291 in 1904 to 133 in 1923 and again to 92 in 1929.

The flour milling industry had 9500 plants in 1899, which increased to a maximum of 11,700 mills in 1909, only to decline by 1929 to 4022 mills. This industry had 32,200 wage earners in 1899, a maximum of 39,400 in 1914 and only 27,000 in 1929. The wheat ground in the

meantime increased continuously from 471 million bushels in 1899 to 546 million bushels in 1929.

These are merely averages from industries selected at random. Of the more striking instances which might be considered is the A. O. Smith plant in Milwaukee with its output of 10,000 automobile chassis frames per day with 208 men in the plant, or the Corning electric lamp plant in New York with its output of 650,000 lamp globes per machine per day, or an increase per man of 550 times that of the method previously employed.

After 1850 displaced workers were reabsorbed in the expansion of general industrial development. Machinery and equipment could be made only by hand-tool methods; consequently tremendous numbers could be reemployed. Today the development of a new industry does not mean any considerable increase in national employment, except temporarily in its formative stages. The moment a new industry reaches the state of organization defined as complete mechanization or, in other words, when it becomes a technological mechanism, employment drops sharply, always tending to further decrease. The production of new equipment for a new industry today means no great change in the numbers employed in machine tool fabrication, as the same process of mechanization has occurred in this field as elsewhere.

All these changes have been made possible by the finding of methods of generating energy other than that of human toil and through the development of a concomitant technology. The cases cited above are but a few instances of the effect of the new methodology which is applicable to any process of production involving repetitive action.

In a simple agrarian society the only means of increasing the standard of livelihood was by the application of more human effort to the soil resources, or, stating it in

another way, only by lengthening working hours. But by the application of technology we now have reached the point where more goods are produced by increasing the total amount of energy consumed and decreasing the energy per unit produced and the process automatically results in a decrease of the amount of human labor required.

It follows that under our present system if technology is extended into more fields of social activity, the rate of production tends to outstrip the rate of population growth and the rate of possible consumption growth, causing simultaneously an ever-increasing unemployment. This process is observable over the period of the last thirty years in every industry for which statistics are available and this includes every major industry on the North American continent.

Malthus assumed sustenance to be the limiting factor of population growth. Even today Dr. Pearl and Prof. East are worried over sustenance requirements of the American social system of tomorrow. Of the total per capita energy consumption of the United States today only about 7% is directly involved in sustenance, the remainder going toward the operation of the social mechanism. The energy involved in the operation of our social structure here in the United States is 15 times as much as the energy consumed in sustenance. So, long before we of this present century have to concern ourselves on this score, we shall be forced to predicate our population growth, on the probable rate of the energy conversion of this continent as a whole.

When the technologist looks at the unfolding events of the past six thousand years, he notes the same changes in political frontiers and systems, in thought and theories, of the outer manifestation of the industrial arts, as noted by other men who have looked at the same train of un-

folding activities. But his insistence upon a quantitative analysis of the technique whereby men have lived leads him to view these changes in a new light. He speaks of the period from the dawn of history to the middle of the eighteenth century as six thousand static years because the social changes that occurred during that period did not appreciably increase man's ability to organize for his use the energy resources of his environment. The changes that occurred were all, therefore, in his view, of a single order of magnitude. In Egypt, Greece, Rome and in Europe of the Middle Ages, the social order succeeded in organizing a particular area of the world's surface and in operating it to obtain the maximum security under its inherent limitations. These limitations prescribed that its upper limits were 2000 kilogram-calories extraneous energy consumption per capita per day. We have no instance in previous social history of an agrarian economy that exceeded these limits. Social mechanics remained in this order of magnitude until the advent of technology in the middle of the eighteenth century, after which the limits of energy consumption rose in the United States to 150,000 kilogram-calories per capita per day. This increase from 2000 to 150,000 kilogram-calories constitutes a social change from one order of magnitude to another. In ancient social mechanisms practically all of the total per capita energy consumption was required for sustenance; in twentieth century America approximately ninety-three per cent of our total energy is consumed in the operation of our social structure. Our society involves a greater expenditure of energy per capita per day than any other social mechanism, past or present. We have achieved a fundamental social change which is susceptible to measurement in physical units.

While the modern technologist lives and does his work under the price system, he has to do his thinking in other

than pecuniary terms; there is no way of avoiding that. The nature of his work, the facts, relations and forces handled by him impose the use of unvarying standards whereby he may make exact measurements. His world is one of materials, energy resources, quantitative relations and rates of energy conversion. Without unvarying standards of measurement the modern processes of production could not be carried on. Quantitative measurements of materials, of energy flow, of energy conversion of work—constitute essentials.

While financiers and business men have occupied positions of authority and control in the fields of production, the technologist has designed the machines, the engines and the continuous processes that account for the present rate of energy conversion. Within narrow limits he has worked with freedom, so that it may be said that he has been the principal agent in bringing on the present industrial capacity. But he has had nothing to do with methods of distribution. Financial business has not only exercised complete control over this field and dictated what should be produced regardless of the resources available, but has also failed in the distribution of the ever-increasing volume of goods and services released by the accelerating rates of energy conversion.

When the technologist looks at the processes of distribution, as he is forced to do at the present juncture, a number of things thrust themselves upon his attention. He notes immediately that all measurements in this field of activity are made by a pecuniary standard that is continuously variable, and that all relations are expressed as prices. He notes that price controls the utilization of energy resources, the rate of flow of materials and labor into the productive processes, and the flow of goods and services into the field of use or consumption. The only feature of the system that seemingly cannot be brought

under the jurisdiction of price control is the rate of energy conversion which is a function, that is to say the outcome, of man's increasing ability in turning things to account. All this constitutes a situation which is obviously alien to the technologist's world of thought, theory and action.

When the technologist looks at the magnitude of our pecuniary wealth, he notes that the items—bonds, mortgages and instruments of loan credit of one sort and another—which foot up to a truly grand total, constitute the same items that foot up to an equally grand total of debt. He also notes that pecuniary wealth cannot be created without first creating a corresponding item of debt. For the purposes of industry, these items are purely fictitious. But he notes that there is a definite purpose behind the creation of these fictitious items in the current scheme, and that they serve the purpose for which they were created. He notes that they afford the borrower a differential advantage in bidding against others for the use and control of industrial processes and materials; they afford him a differential advantage in the distribution of the material means of industry. He also notes that they constitute no physical addition to the material means of industry at large. It is obvious to him that funds of whatever sort are a pecuniary fact, not an industrial one; they serve the distribution of the control of industry, not its materially productive work.

Before the run of current events set in in 1929, this factual statement of the case was not treated kindly by financiers and economists, nor will it be looked upon with favor now. But the nature and meaning of pecuniary wealth is becoming more obvious day by day. The rapidly diminishing "value" of our items of pecuniary wealth (which are at the same time items of debt, the burden of which is increasing at something like an inverse ratio) has in nowise affected the material items of our industrial plant.

The technologist examines our so-called standard of measurements, the monetary unit—the dollar. He notes that it is a variable. Why anyone should attempt, on this earth, to use a variable as a measuring rod is so utterly absurd that he dismisses any serious consideration of its use in his study of what should be done.

He also considers "price" and "value" and the fine-spun theories of philosophers and economists who have attempted to surround these terms with the semblance of meaning. These terms, like the monetary unit, may have had meaning to men in the past but they mean nothing whatsoever to the modern technologist. The standard of measurement is not relevant to the things measured; and the measuring rod and the things, measured as if they were stable, are all variables. We read thousands of newspaper captions such as this: "FARM VALUE CUT BY SLUMP TO 45 BILLIONS. PRESENT WORTH COMPARES WITH 79 BILLION AT WAR'S END—OFF 15% IN YEAR" (1931). And then we read that farm income has fallen from $16,900,000,000 in 1919 to $6,900,000,000 in 1931. It is, of course, quite possible to rationalize this in terms of the functions of the price system; but after it has been rationalized it still remains to the technologist nothing more nor less than an item of nonsense. He simply refuses to think of that item of our technological equipment as waving up and down like that. It doesn't.

To bring production and distribution into balance under such conditions would be much the same as attempting to determine how many pounds of electrical current would come to balance on a scale with a constantly increasing magnitude of fluctuating density. To the technologist the problem of balanced load under the price system is a problem of that order of nonsense. It is not a problem—it is an impossibility.

Moreover, to maintain a balance between production and consumption, with the number of factors involved, requires quantitative calculations that lie beyond the frontiers of arithmetic. And so the technologist does not blame the men of business, finance and politics for not doing what they are not prepared to do. But when he examines the arithmetical impossibility of what they postulate as quantitatively possible, the entire system of financial business takes on the air of unreality; it becomes an impossible world of fairy-tale and magic.

The criterion of successful operation of a modern industry under the ancient price system is that it shall make a monetary profit. Another requirement of industry under a price system is that it shall consider among its expenses the payment of a monetary return upon the capital investment in that industry.

Regarding the first of these requirements, considering other factors to be constant for the moment, the profit possible from a given industry is a direct function of the quantity that can be sold. This fact is largely responsible for the ever insistent demand of business for an ever-increasing production rate and expansion of trade, both domestic and foreign. From the point of view of the individual manufacturer under a price system, the ideal conditions for continued prosperity are an infinite supply of cheap raw materials and labor, and an infinite market, so that there will never be a decline in the rate of increase of production.

In the internal operation of the industry, external factors being considered for the moment constant, the amount of profit that can derive from a given output is an inverse function of the internal cost of production. It has been found that the most efficacious way of reducing internal costs is by means of large scale quantity production by processes as automatic as can be devised. This

requirement dovetails perfectly with the first, or increased output, and the net result is the industrial trends that we have observed in our analysis of the growth of industry on the North American continent.

Another factor which acts in the direction of those already enumerated, is that a monetary return must be paid by the industry to the owner of the invested capital. This is in the form of interest and dividends. In other words, the bonded indebtedness must draw interest. Suppose the rate of this interest on investments is taken to be 5% per annum. Consider the total capital investment in the industries of this continent. Industrial investment is made largely by a very small percentage of the total population, and for that reason the 5% return accruing annually is for the most part re-invested in industry. In order that industry in turn can continue to pay the same per cent return on the added investment it must expand by a similar increment of itself per annum. To continue to satisfy these conditions industry would have to expand at a compound interest rate—the rate of increase of production per annum must itself continuously increase ad infinitum—a physical impossibility.

Another way of increasing profits, under the laissez-faire competition of a price system, is to cut down the cost of production by manufacturing inferior products. This will increase the number of sales on an otherwise saturated market because of the resultant increased replacement rate.

The mathematical, that is, the arithmetical impossibilities of the assumptions which underlie what we are now attempting to do may be readily seen.

Suppose we level production off (as is being done) until an ample mean standard of living compatible with our resource supplies could be provided for the inhabitants. Then under the price system the requirement to

cut internal costs to a minimum would result in an ever-increasing unemployment. If, on the other hand, an attempt were made to keep all the people employed, the increasing rate of output per man hour would result quickly in an over-production of goods that would of necessity extend toward infinity.

Moreover, should industry level off, the lack of new industries or expanded old ones in which to invest the returns already accruing from existing investments, would tend to drive the interest rate to zero.

The problem in its last analysis is primarily one of the effects of different orders of magnitude. The same fundamental characteristics are inherent in the change of magnitude of any mechanism. Consider, for example, vehicles of transportation. The ox-cart is a sturdy slow-motion vehicle. The driver of an ox-cart need have no technical training except to call "whoa-haw" or "gee-haw." If the cart hubs a tree nothing happens. In fact there is not any ordinary error that such a driver could commit that would be of any great consequence either to himself or his vehicle. Consider in like manner the driver of an express train. He must always be awake and alert. He must operate strictly according to the schedule and the signals. Violation of any one of a large number of conditions can and probably will wreck the train, and moreover the magnitude of the wreck will be proportional to the mass and velocity of the train. In a like manner the duty of a train dispatcher, who controls the operation of not one train but many, is even more exacting. Thus we pyramid from a single train to a railway system, and from a railway system to a whole transportation system, and from a transportation system to a whole industrial complex with the same generalizations that the larger and higher powered the industrial system, the more rigorously exacting must be its technical control in order to avert a

wreck, and that moreover the wreck resulting from the lack of such control will be of an order of magnitude proportional to the size and the rate of operation of that mechanism.

Against the picture of the man with the ox-cart or the man with the hoe we now have the accelerating upward sweep of the energy curves and the curves of an enormous total production, and the accelerating declination of the curve of employment, involving millions of men, and still more violent fall of the curve of man hours per unit produced—the sweep of all these curves across the charts dealing with unprecedented magnitudes and numbers constitute unmistakable evidence that the whole system is due to go out of balance in a not distant future.

What are we going to do under the conditions delineated above to avert the disaster that science and technology view as highly probable—which is science's way of saying unavoidable? This question brings us to a subject exceedingly difficult to discuss. For habits of thought and connotations differ in a fundamental way in the world of business, banking and politics from those that obtain in the world of science, technology and the field of materially productive work. Items of ownership, credit, debt, monetary units of value—dollars, shillings, etc.—interest rates and relations, expressed as prices, constitute the realities in the former world; they are unreal and fictitious items in the latter, where energy resources, materials, rates of energy conversion and use forms constitute the real and basic things with which men deal.

Any scheme of social organization, designed to utilize our resources and ability under conditions of security, offered by technology in the name of science, will involve the disallowance of the price system. Such a proposal will appear revolutionary from the viewpoint of the massive interests which now look after the far-flung rights of

ownership and seek vainly to keep the system under control and in balance.

The present is unique in that the ancient ways of politics, and the firmly established strategies of modern finance and business, may be observed in operation, while the ways of life and habits of thought are being transformed by the impact of modern science and the methods of modern technology. In contrast to the devious ways of politics, the fumbling methods of finance and business, with the concomitant, mysterious movements of prices and values and the anthropomorphic discussions concerning what The Market "wants to do"—all of which is carried as conspicuous news—we have the methods of science and technology. Our daily life throws us into intimate relations with the peculiar competence of modern technology. Out of this contact we have developed a high regard for the accuracy of its factual analyses, its mathematical measurements and handling of materials and forces, and for the validity of its procedure.

Although we live in a world of price and of speculation, of ever-increasing magnitude of fluctuations of "value" of bonds, mortgages, equities, land, building, salaries, wages, savings; and an ever-decreasing number of jobs available; of numbers unemployed;—the increase of insecurity and of want, in the face of rapidly-increasing industrial competence—these things force us to turn to science and technology, since the competence of all other agencies dwindle in our esteem.

To modern civilized men, science has become the court of last resort. The explanations offered in the name of science are accepted under the new order of common sense within which we live and do our work. And so at the present time we are witnessing, in the body of beliefs that stand to support the price system and the current institutional scheme, a repetition of what has taken place re-

peatedly within the fields of belief which sought to support systems and institutions beyond their allotted day.

When the oncoming march of physical science arrived in the field of chemistry, it found its way blocked by alchemists, philosopher's stones, and phlogistonites. Its pace was retarded, its movement checked but for a moment, and it rolled on to occupy the entire field once so completely filled with all manner of superstitious theories and opinions. It ended with the total exclusion and complete intolerance of the obsolete methods of philosophic speculation in these fields. The same onward march has been proceeding. It has driven the astrologer out of astronomy, the geographer out of meteorology and seismology, the barber out of blood-letting, and Providence out of the field of bacteriology.

Current events have already declared the pressing need for change. Already we hear the rumblings of discontent, that voices itself in Marxian philosophies, and the cry of fear that calls for a dictatorship. And now come the men of physical science who state in no uncertain terms that Bolshevism, Communism, Fascism, are utterly impotent to deal with the advanced technological situation in which we, of the North American continent, find ourselves placed. Which of these systems of thought and action will be given the mandate when the present system fails to function is impossible to say. But one thing is clear: modern common sense is now calling upon physical science and technology to extend the frontiers of their domain.

PART II

Integrating the Physical Sciences in Attacking Social Problems

Technocracy is a research organization, founded in 1920, composed of scientists, technologists, physicists, and biochemists. It was organized to collect and collate data on the physical functioning of the social mechanism on the North American continent, and to portray the relationship of this continent and the magnitude of its operations in quantitative comparison with other continental areas of the world. Its methods are the result of a synthetic integration of the physical sciences that pertain to the determination of all functional sequences of social phenomena.

Technocracy makes one basic postulate: that the phenomena involved in the functional operation of a social mechanism are metrical. It defines science as "the methodology of the determination of the most probable." Technocracy therefore assumes from its postulate that there already exist fundamental and arbitrary units which, in conjunction with derived units, can be extended to form a new and basic method for the quantitative analysis and determination of the next most probable state of any social mechanism. Technocracy further states that, as all organic and inorganic mechanisms involved in the opera-

tion of the social macrocosm are energy-consuming devices, therefore the basic metrical relationships are: the factor of energy conversion, or efficiency; and the rate of conversion of available energy of the mechanism as a functional whole in a given area per time unit. Technocracy accordingly establishes a new technique of social mensuration, that is to say, a process for determining the rates of growth of all energy-consuming devices within the limits of the next most probable energy state.

The Energy Survey of North America now being conducted by Technocracy in association with the Industrial Engineering Department of Columbia University and the Architects' Emergency Committee * has found that employment of this method has not only yielded new data but has endowed already existing data with a new significance. As the above method is one of measurement, it follows axiomatically that all processes of evaluation are excluded. Value has no metrical equivalent.

Value is defined by the economists as the measure of the force of desire. It has its physical manifestation in any one commodity unit by which all other commodities or services are evaluated. Any society using a commodity method of valuation shall herein be said to be employing a price system. A 'social steady state' is a social mechanism whose per-capita rate of energy conversion is not changing appreciably with time. Social change, on the other hand, may be defined as the change in the per-capita rate of energy conversion, or the change from one order of magnitude to another in the social conversion of the available energy. All social history prior to the last century and a half, viewed technologically, may therefore be described as the record of a steady state. Only within the last hundred and fifty years has there been introduced a technique

* The Emergency Relief Committee of New York has recently assisted the project by supplying research workers from its lists of the unemployed.

that has specifically caused social change. Technology, as the executor of physical science, is the instrument for effecting social change.

During the 200,000 years prior to 1800 the biological progression of man, in his struggle for subsistence on this earth, had advanced so far that the total world population in that year reached the approximate number of 850,000,000. During the subsequent 132 years world population has attained such heights that it now exceeds a total of 1,800,000,000; in other words, the population increase in the last 132 years has been greater than it was in the previous 200,000. Most of this increase in the human species has been made possible by the social introduction of technological procedures, that is, change in the means whereby we live as brought about solely by the introduction of technology.

A century ago these United States had a population of approximately 12,000,000, whereas to-day our census figures give a total of over 122,000,000—a tenfold increase in the century. One hundred years ago in these United States we consumed less than 75 trillion British thermal units of extraneous energy per annum, whereas in 1929 we consumed approximately 27,000 trillion British thermal units—an increase of 353 fold in the century. Our energy consumption now exceeds 150,000 kilogram calories per capita per day; whereas in the year 1800 our consumption of extraneous energy was probably not less than 1600 or more than 2000 kilogram calories per capita per day.

The United States of our forefathers, with 12,000,000 inhabitants, performed its necessary work in almost entire dependence upon the human engine, which, as its chief means of energy conversion, was aided and abetted only by domestic animals and a few water wheels. The United States to-day has over one billion installed horse-power. In 1929, these engines of energy conversion, though op-

erated only to partial capacity, nevertheless had an output that represented approximately 50 per cent of the total work of the world. When one realizes that the technologist has succeeded to such an extent that he is to-day capable of building and operating engines of energy conversion that have nine million times the output capacity of the average single human being working an eight-hour day, one begins to understand the significance of this acceleration, beginning with man as the chief engine of energy conversion and culminating with these huge extensions of his original one-tenth of a horse-power. Then add the fact that of this 9,000,000 fold acceleration 8,766,000 has occurred since the year 1900.

Stated in another way, if the total one billion installed horse-power of the United States were operated to full capacity, its output would be equivalent to the human labor of over five times the present total world population.

Physical science has outdistanced present social institutions to such an extent that man, for the first time in history, finds himself occupying a position in which a complete utilization of his knowledge would assure the arrival of certainty in a continental social mechanism. Man, in his age-long struggle for leisure and the elimination of toil, is now at last confronted not only by the possibility but by the probability of this arrival. Such a new era in human life is technologically dependent only upon an extension of the physical sciences and the equipment at hand.

But the pathway to that new era is blockaded with all the riffraff of social institutions carried over from yesterday's seven thousand static years. The law of the next arrival is depicted by the Gaussian curve of probability, or the next most probable energy state.

America faces the threshold of the new era with the

greatest total debt load ever carried by any social mechanism, a debt of over $218,000,000,000 against her physical equipment and its operation. With the number of unemployed greater than the total population of a century ago; with one of the most providential geologic set-ups of any continental area; still possessing more energy and mineral resources than any like area on the world's surface; having more than one billion installed horse-power of prime movers wherewith to degrade available energy into use-forms; possessing a personnel of over 300,000 technically trained men in many varied engineering fields and more than 4,000,000 men partially trained and functionally capable of operating the greatest array of productive equipment ever at the disposal of man—with all this, we have, nevertheless, failed to profit from technological advances, and accordingly find ourselves, for the first time in history, with an economy of plenty existing in the midst of a hodgepodge of debt and unemployment.

America can expect no help in the solution of this problem from any current social theory. What has the world to offer toward such a solution? Europe discovered America in 1492. To-day America is further away from Europe than she was when Columbus sailed. The America of to-morrow will necessitate a rediscovery by Europe. European culture and traditions have nothing of worth-while importance to offer America in this twilight period preceding the dawn of a new era. No European importations of social or political theory can have the slightest value in solving the operational problems facing America to-day. Arising out of areas that lack adequate physical equipment and trained personnel, areas in which only a low percentage of the population is disciplined in engineering thought processes, European socio-political philosophies and theories are the natural outgrowth of a more classified division and orientation of the entrepreneur

sectionalism of the price system. No theory of social action or governance now existing or proposed in Europe would in any way be endemic to that unique set-up of geologic conformation, technique, equipment, and personnel peculiar to North America.

Russia, of whose population 92 per cent were tillers of the soil under the *ancien régime* and which had meagre technical facilities and more musicians than technologists, found itself in the position of being compelled to inaugurate an industrial era under a communistic price system of production. Soviet Russia was forced to call upon the outside world for technical assistance in order to perpetrate reproductions of factories already obsolescent from an obsolescent price system. Russia, in its Parthian retreat from capitalism, has scored but a Pyrrhic victory. It mistook the name tag of one phase of the price system for that system's entirety; it abandoned the tag, but retained the essential mechanics.

To approach social phenomena by substituting Hegelian for Aristotelian dialectics may be an interesting intellectual pastime, but it has no functional importance: it is but one more recrudescence of the philosophic futility implicit in European tradition.

The England of the Black Prince, with its population of 5,000,000, its wealth of oak timber, its hearty people drinking deeply of ale (made not from hops but from barley malt), its original resources of copper, lead, tin, iron ore, and coal—this England developed under the price system of production. Inevitably, like the prodigal son, England went forth into the world and squandered its inheritance among the harpies of world trade and debt creation.

The United Kingdom, with an area of 121,000 square miles and a population of 49,000,000,—or a density of 400 inhabitants per square mile,—with arable land amount-

ing to only 23 percent of the total national area, finds itself in the physical position of possessing only a single energy resource, and that a declining one. Its tin gone, as well as its copper and lead, its iron requiring 56 per cent foreign beneficiation in order to produce steel, its coal becoming more and more difficult to mine, the United Kingdom is fast retrogressing from its position as the possessor of easily available energy to its next most probable energy state as two islands off the coast of the European continent. A valiant race, fighting a losing battle, is displaying an admirable fortitude in the crisis that is resulting from excess population, declining resources, and obsolescent equipment operated by the antiquated methods of a price system.

The United Kingdom will be forced by internal pressure to adopt measures even more extreme than the flight from the gold pound. It may be compelled by the growing disparity between its own industrial operation and the world trade balance to such extremities as abandonment of monetary currency and the accompanying credit structure. In that event, a British currency of pure fiat power might be attempted as a last desperate resort. The present deflationary programme may be reversed in the near future to one of inflation, a last straw grasped at in England's struggle for the export markets of the world. Sooner or later, in spite of British imperialism, the United Kingdom, under a price system, will be forced to meet a situation that will be increasingly grave in its internal operation. There remains only the colonizing soporific of bestowing a surplus population of 35,000,000 on the overseas Dominions.

Fascism, that strange but natural partnership of the Italian political state and vested interests, is a process of consolidating all the minor rackets into one major monopoly. Such a condition brought with it the sequelæ

of discipline and sanitation that necessarily accompany complete trustification. Italy, which is insufficiently supplied with energy and mineral resources, which possesses only a limited amount of water power and volcanic heat, which has some mercury and sulphur but no coal, oil, or gas, no iron ore, copper, tin, lead, or zinc, and which lacks a high enough percentage of arable land to grow sufficient foodstuffs for its own needs—Italy belongs to the geologic order of areas that can not create and operate an industrial energy civilization. Fascist Italy is rapidly increasing its dangerous overload of population by granting national bonuses to large families in futherance of its *mare nostrum* policy. Fascism is an attempt at a last-ditch defense of a price system, an effort to maintain an unbroken front against oncoming social change, but this unbroken front is spurious in that it is being temporarily maintained by foreign importation of energy-resource materials, supplemented by the manna of the Lord.

Egypt, Assyria, Greece, Rome, and, in the Victorian age, Imperial Britain have all led the world in their day; each in turn has been the vanguard of civilization. The past is strewn with ruins of empire. Now there is but one continental area that from the standpoint of its geologic set-up, equipment, personnel, and the state of its technology is competent and ready to inaugurate a new era in the life of man.

America stands on the threshold of that new era, but she will have to leave behind all the wish-fulfilling thought and romantic concepts of value that are the concomitants of a price system. So, too, all philosophic approaches to social phenomena, from Plato to—and including—Marx, must functionally be avoided. Economics, that pathology of debt, not containing within itself any modulus or calculus of design or operation, must likewise be discarded

with the other historical antiquities. No political method of arriving at social decisions is adequate in continental areas under technological control, for the scientific technique of decision arrivation has no political antecedents.

Under a price system wealth arises solely through the creation of debt. In other words, price-system wealth consists of debt claims against the operation of the physical equipment and its resultants. Physical wealth, on the other hand, is produced by converting available energy into use-forms and services. The process of being wealthy is the degradation of the resultants of the above conversions into complete uselessness—in other words, total consumption. To be physically wealthy is not to own a car but to wear it out. Technology has introduced a new methodology in the creation of physical wealth. It is now able to substitute energy for man hours on the parity basis that 1,500,000 foot pounds equals one man's time for eight hours. National income under the price system consists of the debt claims accruing annually from the certificates of debt already extant. Physical income within a continental area under technological control would be the net available energy in ergs, converted into use-forms and services over and above the operation and maintenance of physical equipment and structures of the area.

Individual income under a price system consists of units that are not commensurate with the quanta by which the rate of flow of the physical equipment is measured, and upon which the social mechanism depends for its continuance. Individualism is therefore favored under a price system, since individualism can obtain a monetary equivalent proportional to the individual's ability to create debt. Individual income under such a system therefore depends on the extent to which advantage is exercised by means of the interference-control that is dominant throughout the whole system of debt creation.

Individual income under technological control would consist of units commensurate with the quanta by which the rate of flow of the physical equipment is measured throughout the entire continental area. The unit income of the individual would be determined by the period necessary in that area to maintain a thermodynamically balanced load, that is to say, the time it takes for a complete cycle of the operating and production procedures to be completed.

Any unit of *value* under a price system is a certification of debt. Any unit of *measurement* under technological control would be a certification of available energy converted. Such units of certification would have validity only during the balanced load period for which they were issued. This method of producing physical wealth and measuring its operation precludes the possibility of creating any kind of debt. It also eliminates the entire domain of philanthropy. Furthermore, all bonds, financial debentures, and other instrumentalities of debt would cease to exist, since they do not have one iota of usefulness in the physical operation of such an area under technological control.

Technocracy proposes no solution, it merely poses the problem raised by the technological introduction of energy factors in a modern industrial social mechanism. Continental America possesses all the essential qualifications for such a mechanism—sufficient energy and mineral resources; adequate water precipitation, more than enough arable land of proper chemical stability; highly developed technological facilities backed by a trained personnel; powerful research organizations. All these things are entirely sufficient to assure the continuance of a high energy standard of livelihood for at least a thousand years, if they are operated on a non-price basis with the technological means known at present.

America stands now at the crossroads, confronting the dilemma of alternatives. The progression of a modern industrial social mechanism is unidirectional and irreversible. Physically this continental area has no choice but to proceed with the further elimination of toil through the substitution of energy for man hours. There can be no question of returning to premachine or pretechnological ways of life; a progression once started must continue. Retrogressive evolution does not exist.

A SELECTED READING LIST
FOR LAYMEN FROM THE LITERATURE OF SCIENCE

DANTZIG, TOBIAS: *Number*, the language of science, a critical survey written for the cultured non-mathematician. New York, The Macmillan Co., 1930. viii, 260 pages, plates.

Mathematics has always stood in the popular mind as a symbol of everything abstruse, remote, final, hopelessly rigorous and correct: for this view we are still much indebted to the mathematical idealism of Pythagoras and Plato. Actually, however, no science has grown so slowly, followed more false leads, gone more astray in bogs of speculation and sterile intellectual jugglery. This excellent volume by a member of the United States Bureau of Standards can be recommended to the interested layman not only for the human charm with which the author invests the "Queen of the Sciences," but for the substantial historical background it provides for a true appreciation of mathematical thought. Dr. Dantzig begins with "number-sense" and continues through the early gropings of arithmetic, geometry and algebra; discusses the rise and growth of symbols; the Irrational, Incommensurate, and Transcendental. Guided by such great figures as Leibnitz, Fermat, Newton, Euler, Cantor, Gauss, Dedekind, Hilbert, we journey from zero to the infinite: yet, if we are wise, we will recognize—as does Technocracy—that every step forward in this vast domain has not only been gained at a heavy cost, but that the gain itself is measured, ultimately, by the success with which a new mathematical procedure can be utilized (through science and technology) to solve some problem of the actual world. If, as David Hilbert said, mathematics is a game played according to certain rules, it is nevertheless a game played by fallible beings in their unending efforts not merely to understand but to dominate Reality.

Maxwell, James Clerk: *Matter and motion.* Reprinted, with notes and appendices by Sir Joseph Larmor. London, The Sheldon Press, (American distributors, The Macmillan Co.), 1925. xv, 163 pages.

This remarkable little book by one of the greatest mathematical physicists of all time was first published in 1877: its reissue in 1920 is sufficient proof of the vitality inherent in all fundamental scientific thought. It is recommended because of the clear and rigorous way in which are developed the concepts of Force, Motion, Work, Energy, and "material systems." The treatment, although advanced and frequently mathematical, should not prove a stumbling block to anyone with a fair knowledge of physics and a genuine interest in the methods of science—which are, ultimately, those of strict observation, correlation, and exact quantitative measurement. Particular attention is directed to the chapters on Force and Energy, which are basic to all phenomena exhibiting motion, and thus fundamental to an understanding of Technocracy. If the reader will strive to appreciate and share Clerk Maxwell's lifelong interest in the "go" of things, he will not only gain much from a careful study of this book, but find it both possible and profitable to approach social phenomena with something of the objective clarity which has always distinguished the conquests of science, and which now, through Technocracy, seeks to become effective in the domain hitherto consecrated to the speculations of philosophy, the animosities of politics and the values of economics.

Andrade, E. N. da C.: *The mechanism of nature;* being a simple approach to modern views on the structure of matter and radiation. London, G. Bell & Sons, Ltd., 1930. xii, 170 pages.

The seven chapters which make up this extremely readable book by one of England's best known physicists consider such important matters as heat and energy, sound, light and radiation; electricity and magnetism; the atom and the Quantum Theory. Professor Andrade has remarkable talent in exposition, and the reader is advised not to permit his enjoyment of the author's style to undermine his attention to the matters in hand. Particularly noteworthy is the chapter on heat and energy, which provides excellent

material to supplement the more abstruse treatment of those subjects in Clerk Maxwell's book. The problems of heat transfer and energy exchanges are well posed and clarified, as is also the theory of probabilities as it applies in the kinetic theory of gases. Light and radiation, sound and vibration (the latter being Andrade's special field) are skillfully discussed, with many examples from common life and references to such critical experiments as those of Michelson and Morley. The chapters on the atom and on Quantum Theory are among the best short discussions of these rapidly changing subjects thus far written for the layman. Largely factual in character—and to this extent liable to correction through subsequent discoveries—this little volume will nevertheless go far to establish a finer appreciation of the importance of exact observation and close reasoning in dealing with natural phenomena: of which so many are now irrevocably part and parcel of the social macrocosm studied by Technocracy.

CAJORI, FLORIAN: *A history of physics in its elementary branches*, including the Evolution of Research Laboratories. Revised and enlarged edition. New York, The Macmillan Co., 1929. xiii, 424 pages.

There can be no better foundation for an understanding of the physical sciences than a sound general knowledge of their history. For physics proper such a knowledge is admirably supplied by this short but scholarly and readable volume by one of America's foremost historians of mathematics. The somewhat cursory treatment of ancient and medieval science (which receives only thirty pages) is followed by chapters on the Renaissance (Copernicus, Kepler, Stevinus, Galileo, Gilbert, Francis Bacon), and on the seventeenth and following centuries. The gradual progression of quantitative physical ideas is illustrated by constant reference to the work of such pioneers as Newton, Boyle, Black, Lavoisier, Laplace, and Huygens; with each step forward the basic concept of energy is more firmly established until in the twentieth century, atomic physics, radioactivity, and the brilliant formulations of Max Planck set up a challenge to all old ways of thinking about the world and the universe which the future will have to heed. Cajori's book is recommended principally because it gives a sense

of that inevitable drawing together of scientific method and social thought which forms the basic conviction of Technocracy and will prove its final justification as a fertile approach to the problems of society considered as a functioning organism.

MOTT-SMITH, MORTON: *This mechanical world;* an introduction to popular physics. New York, D. Appleton & Co., 1931. xvi, 233 pages, illus., bibl. New World of Science Series, ed. by Watson Davis.

If, as Technocracy has indicated in no uncertain terms, modern society is becoming more and more a dynamic phenomena, an understanding of the principles of dynamics might well be given the right of way over the a priori speculations of traditional economics and sociology. Mott-Smith's volume is admirably suited to provide the intelligent, non-technical reader with a background in this great branch of the physical sciences. Believing that "it is important for our security and progress to know and understand the physical environment in which we live," Professor Mott-Smith loses no time in getting at the heart of his subject. Hydrostatics, inertia, force, acceleration; the laws of motion and gravitation; mass, weight and momentum; the conservation of energy and the forms of energy; old beliefs and modern theories of physical phenomena—these are a few of the things discussed, with adequate references to the great pioneers from Archimedes through Galileo to Newton, Maxwell and Ernst Mach. The reader is made to realize the importance of clear ideas and exact measurement in dealing with natural phenomena, and the frequent use of homely examples, such as the lever, inclined plane, pulleys and projectiles, help to drive home the basic concepts of dynamics—particularly those which show the inseparable relationship between energy expended and work accomplished. From the viewpoint of Technocracy, this popular exposition of mechanics is commendable not only for the skill shown in presenting difficult material but because this material, properly assimilated, will give the layman a keener appreciation of the impersonal forces underlying even the last stronghold of human values—society.

Cannon, Walter B.: *The wisdom of the body.* New York, W. W. Norton & Co., Inc., 1932. xv, 312 pages, diagrams, bibl.

Recommended by Technocracy because it is one of the few recent books which describe that primitive biological prime mover, Man, in the terms and with the special objective methods of science. The author, Dr. Cannon, is not only one of America's foremost living physiologists, who has been widely honored here and abroad, but also a very gifted expositor of his specialty. In this volume, intended for the layman, he reveals the human body as a mechanism of extraordinary complexity and adaptability: with each of the major functions—respiratory, digestive, circulatory and reproductive—there are associated others that express themselves in determinate ways, and in entire accordance with the principle of the conservation of energy. The outcome of all this largely automatic internal activity is the attainment and maintenance of what Professor Cannon calls "homeo-stasis" and which he defines as "the coordinated physiological processes which maintain most of the steady states in the organism"—that is to say, which insure the proper stability against environmental and physiological disturbances. The use of the expression "steady states" is peculiarly appropriate, for it is one of the terms widely used in thermodynamics and is employed also by Technocracy to describe those social structures in which that highly stabilized engine, Man, was the principal engine of energy conversion. Professor Cannon, in a suggestive final chapter, attempts a parallel between physiological and "social" homeo-stasis which should not be taken too seriously: he does, however, recognize that stability results from an *even flow* of the materials of the organism. This is a shrewd approach to the view of Technocracy, that smooth social operation depends solely upon the rates of flow of the available physical energy as converted into use forms and services.

Petrie, Flinders: *Social life in ancient Egypt.* London, Constable & Co., ltd., reissue, 1932. viii, 210 pages.

Sir Flinders Petrie needs no introduction to those with any interest in, or knowledge of, archaeology or the history of human cultures. To a thoroughgoing scholarship and extensive field ex-

perience he adds what, from the point of view of Technocracy, is of supreme importance to all engaged in historical research: keen appreciation of the natural factors on which all human societies depend, and by which alone they can function adequately. It is for this reason that his small but remarkably well-informed volume on Egyptian social life is included here: in six chapters we are given a picture of an ancient society as it actually worked under the special conditions imposed by nature. We see the framework of this society, bounded by king, priest, warrior and slave; the conditions of labor are set forth, and authentic details regarding such colossal achievements as the Pyramids enable us to realize both the pathos and the terrific efficiency of the institution of human slavery—that historic progenitor of technology and the machine. The administration of Egypt and the intricacies of court life; existence in town and country; legal, political and social customs (many of them suggestively "modern"); and, particularly to be noticed, very full accounts of commerce, manufactures and trades, primitive industries; weights and measures; construction and national defense. In effect, what Sir Flinders Petrie has done in 200 compact pages is to give us one of the most instructive accounts we know on ancient society as a functioning organism rather than as a static repetition of dynastic and political changes on the level of nationalist chicanery. One reason for this stimulating dynamic attitude may be found in these words taken from the opening chapter: "It is not too much to say that the discoverer is the maker of society. Every step of discovery or invention reacts on the structure of social relations. We can see this around us to-day; . . . . the present use of electric power and of the internal combustion engine for motors, will entirely alter the relation of town and country." To this extent at least, Technocracy gladly acknowledges Sir Flinders Petrie as a worthy ally.

Voskuil, Walter A.: *Minerals in modern industry.* Philadelphia, John Wiley & Sons. 1930. 350 pages.

Technocracy is able to recommend this book as containing one of the most readable and concise summaries available of the mineral position of the United States in relation to the rest of the world; and also because of the emphasis it lays upon the basic

role played by minerals in our present industrial social mechanism. The author's occasional departure from the scientific terms of mass and energy and his discussion of certain phases of the question in the non-scientific terms derived from economic theory (in particular those centering about "value" and "monetary costs") would be much more objectionable had he not made clear his adherence to a broad social welfare point of view. This view has led him to recognize the imperative need for the conservation and wise use of mineral resources, thus automatically invalidating his references to the traditional price system methods of evaluating and operating the functional sequences of industry. It is to just such paradoxes and contradictions in current thought on social problems that Technocracy has consistently been directing public attention.

LEITH, C. K.: *World minerals and world politics.* New York, Whittlesey House (McGraw-Hill Co.), 1931. 193 pages.

Professor Leith is the head of the Geology Department of the University of Wisconsin and one of the leading authorities on world mineral resources. He is also a wealthy owner of iron interests. This dual position of the author is faithfully reflected in his book. Technocracy regrets that it can unreservedly recommend only those chapters dealing with Professor Leith's proper scientific domain: world minerals. In these he discusses with the skill and competence possible only to one thoroughly familiar with the subject the geographical areas of the earth with regard to minerals, emphasizing the close interdependence of these areas, their various strong points and weaknesses. Here he almost recognizes some of the conclusions long held by Technocracy: that actual wealth is the degradation of available energy into socially desirable use forms and services, and is thus measurable only in the quantitative units derived from the physical sciences. The chapters on world politics in relation to minerals, however, appear to have been written by the author in his capacity as owner of large iron interests, for in them he relaxes in scientific detachment, attempting to elucidate ways and means for the further exploitation of mineral resources according to the still accepted canons of the price system and of that "absentee owner-

ship" so shrewdly analyzed by Thorstein Veblen. Technocracy therefore discards these chapters as having no relevance to the subject in hand, and as being inspired by an attitude with which it has nothing in common.

Usher, Abbott Payson: *A history of mechanical inventions.* New York, McGraw-Hill Book Co., 1929. 390 pages, illus., bibl.

This well-documented and generously illustrated volume is of major importance to those who wish to acquire a correct insight into the technological factors of modern life. Disregarding the somewhat loose psychological speculations on the nature of invention in general (particularly the references to "Gestalt theory" of human behaviour) the reader may concentrate his interest in the fascinating story that begins with the "eolipile" steam toy of Hero and comes down to the internal combustion engine of the modern motor car and aeroplane. Despite the steady efforts of man to eliminate toil through mechanical aids, and the support of a growing body of exact scientific knowledge (here again Galileo scored many triumphs), the actual saving in human labor was negligible until James Watt inaugurated the Age of Power by his improved steam engine about the time of America's Declaration of Independence. Professor Usher is particularly full in his discussions of water wheels and wind mills, clocks, and watches, the invention of printing; textile machinery; and he has an unusually valuable chapter on the mechanical genius of that great forerunner of modern technology, Leonardo da Vinci. Other chapters on machine tools, quantity production and power complete a volume which Technocracy can thoroughly recommend for the clear understanding it will give intelligent readers of the slow progression of man through the centuries of toil to the rapidly accelerating Epoch of Power. Professor Usher's general point of view is well stated in the following sentence, "The technological sciences furnish the account of the most important single factor in the active transformation of the environment by human activity"—provided that by "human activity" we understand, not labor in the sense intended by Adam Smith or even the Physiocrats on whom he drew so generously, but "ex-

ploitation by man of extraneous physical energies converted to his use through technological means."

SODDY, FREDERICK: *Wealth, virtual wealth and debt, the solution of the economic paradox.* New York, E. P. Dutton & Co., 1926. 320 pages.

This, the only volume in the group dealing in any specific way with the subject of economics, is included because the author is primarily a scientist of notable achievements in the field of physics. Nobel Prize winner in chemistry, discoverer of isotopes, collaborator with Lord Rutherford in pioneer researches on atomic structure and radio-activity, Professor Soddy attempts here a very interesting thing: the reduction of Economics to quantitative methods of analysis. In view of the hasty charge of plagiarism brought against Technocracy in connection with this book, it is desirable to point out: first, that Soddy's earlier chapters (up to the sixth) give a valuable account of the social implications of modern science, particularly in the fields of thermodynamics and energy-exchanges; second, that the necessity for interpreting social forces in terms of dynamic physical forces susceptible to measurement and control, is very pressing; third, that through inability, or unwillingness to follow these vital premises through, Soddy still maintains the traditional view of "wealth" as bearing some functional relation to the "value medium" of money rather than—as is *basic* to Technocracy—to quantitative units derived from the conversion of available physical energy into use-forms and services. This peculiar confusion of thought is reminiscent of Tycho Brahé's ingenious effort to reconcile the exploded Ptolemaic cosmogony with the Copernican, or of Joseph Priestley's last ditch defense of the "Phlogiston theory" his own experiments did so much to discredit. For this reason Technocracy, however appreciative of Professor Soddy's valiant and suggestive attempt to recast economics in a scientific form, must qualify its recommendation of this volume by a warning which may be thus generalized: Economic theory, as it has come down to us from "yesterday's seven thousand static years," can neither be reconciled with, nor recast by, these methods of the physical sciences now functionally dominant in our modern industrial mechanisms: it must be discarded.

A NOTE ON THE WORK OF THORSTEIN VEBLEN

There has been much discussion concerning the origin of the body of ideas for which the term Technocracy now stands. Speculation concerning this point has focused attention upon the work of Thorstein Veblen as the source of inspiration, with particular reference to the "Engineers and the Price System" as the animating force. Such conclusions are quite contrary to the facts.

Shortly after the close of the War, Scott was introduced to Veblen by a mutual acquaintance who recognized that the two men had come to quite similar conclusions concerning the operation of the social mechanism—Scott by way of physical science and Veblen by hacking his way through the preconceptions of economic science. In "The Engineers and the Price System" which was written after contact with Scott, Veblen indulges in extrapolations that are at wide variance with the work since accomplished by Technocracy.

Veblen's position at that time is expressed in his published works, such as "The Theory of Business Enterprise," "The Instinct of Workmanship," "The Place of Science in Modern Civilization," "Imperial Germany and the Industrial Revolution." Scott was not at that time acquainted with the works of Veblen and although Scott's published statements are of a later date, to those who knew both, during the years immediately following the War when Technocracy was organized, there can be no

question as to the complete independence of the two men and their theories. You cannot state Scott's theory in terms of Veblenian formulations, nor can you express Veblen's economic theory in terms of Scott's theory of energy determinants.

Veblen was working at that time under the point of view expressed in his note "Why is Economics not an Evolutionary Science" to be found in "The Place of Science in Modern Civilization." Scott approached his work under the theories of physical science. It was this approach, by way of physical science, to the problems of explaining and operating the social mechanism that enabled him to take the next all important step: the substituting of a metrical for the prevailing "value" interpretation of the social mechanism. In this manner, he was able to reduce such generalized concepts as "the accelerating productivity of the state of the industrial arts" to quantitative terms with which physical science and technology could deal.

In their treatment of "price" (Veblen in "The Theory of Business Enterprise" and Scott in Part II of this book) and its bearing upon the productivity of the industrial system it is difficult to distinguish between the two points of view. To both, "price" is an independent variable that intrudes and, through its controls, serves to throw the system out of balance. Nor is there any important distinction to be drawn from their handling of debt.

The body of ideas for which Technocracy acts as spokesman is seemingly foreshadowed in the recent drift of modern commonsense as it has gradually taken form under the impact of physical science and technology. Veblen was caught in that drift and he gave it both acceleration and direction. Scott likewise was caught in it; but being free of the preconceptions of economic science,

he was able to turn his knowledge of physical science to bear directly upon the problems of the physical operations of a social mechanism that had already passed under the dominating control of science and technology.

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